

CLAIMS

1. A method for processing a surface of a workpiece comprising:
  - selecting a set of reaction parameters;
  - loading the workpiece into a reaction chamber;
  - pumping on said reaction chamber until a pressure according to said selected reaction parameters is achieved;
  - translating the workpiece at a constant rate across said chamber according to said selected reaction parameters;
  - flowing simultaneously into said chamber a precursor gas, a purge gas, and an input gas according to said selected reaction parameters;
  - evacuating said purge gas and any gases/residuals in vicinity of said purge gas to prevent mixing of the precursor and input gases; and
  - delivering a beam of electromagnetic radiation according to said selected reaction parameters into the flow of said input gas to produce a high flux of point of use generated reactive gas species which reacts with a surface reactant formed from said precursor gas impinging on the surface of the workpiece at selected locations.
2. The method of claim 1 further comprises flowing into said chamber a transmission gas.
3. The method of claim 1 wherein said pressure is from about 0.1 Torr to about 100 Torr.

4. The method of claim 1 wherein said surface reactant and said reactive gas species react to form a monolayer of a material on the surface of the workpiece.
5. The method of claim 4 further comprises checking formation of said monolayer of said material on the surface of the workpiece for completeness according to said selected reaction parameters.
6. The method of claim 1 further comprises purging completely said chamber and removing the workpiece from said chamber after completion of said processing according to said selected reaction parameters.
7. The method of claim 1 further comprises directing said beam through a window of said chamber.
8. The method of claim 1 further comprises causing relative motion between the workpiece and said beam.
9. The method of claim 1 wherein said flows of said input gas, precursor gas and purge gas are provided from a dispenser unit, wherein said dispenser unit further includes a pair of evacuation ports to evacuate at least said purge gas.

10. The method of claim 9 further comprises causing relative motion between the workpiece, said beam, and said dispenser unit.

11. The method of claim 1 wherein the workpiece comprises a semiconductive substrate.

12. An atomic layer deposition method for forming monolayers on a surface of a substrate, comprising:

exposing the surface of the substrate to a precursor gas to form a surface reactant thereon;

providing an input gas above the surface of the substrate simultaneously with said precursor gas;

preventing the mixture of said precursor gas and said input gas with a purge gas;

directing a beam of electromagnetic radiation into said input gas to produce a high flux of generated reactive gas species; and

reacting said generated reactive gas species with said surface reactant to form at least a monolayer on the surface of the substrate.

13. The method of claim 12, wherein said generated reactive gas species is selected from the group consisting of the noble gases, nitrogen, hydrogen, oxygen, and combinations thereof.

14. The method of claim 12 wherein the generated reactive gas species is selected from the group consisting of NO, OH, NH, N, F, CF<sub>3</sub>, CF<sub>2</sub>, CF, NF<sub>2</sub>, NF, Cl, O, BCl<sub>2</sub>, BCl, FCO, and combinations thereof.
15. The method of claim 12 wherein the input gas is selected from the group consisting of N<sub>2</sub>O, NO<sub>2</sub>, NH<sub>3</sub>, H<sub>2</sub>, H<sub>2</sub>O, N<sub>2</sub>, O<sub>2</sub>, O<sub>3</sub>, CCl<sub>4</sub>, BCl<sub>3</sub>, CDF<sub>3</sub>, CF<sub>4</sub>, SiH<sub>4</sub>, CFCl<sub>3</sub>, F<sub>2</sub>CO, (FCO)<sub>2</sub>, SF<sub>5</sub>NF<sub>2</sub>, N<sub>2</sub>F<sub>4</sub>, CF<sub>3</sub>Br, CF<sub>3</sub>NO, (CF<sub>3</sub>)<sub>2</sub>CO, CF<sub>2</sub>HCl, CF<sub>2</sub>HBr, CF<sub>2</sub>Cl<sub>2</sub>, CF<sub>2</sub>Br<sub>2</sub>, CF<sub>2</sub>CFCl, CF<sub>2</sub>CFH, CF<sub>2</sub>CF<sub>2</sub>CH<sub>2</sub>, NH<sub>3</sub>, CHF<sub>3</sub>, fluorohalides, halocarbons, and combinations thereof.
16. The method of claim 12 wherein the substrate is semiconductive.
17. The method of claim 12 wherein said electromagnetic radiation is ultraviolet radiation.
18. The method of claim 12 wherein preventing the mixture of said precursor gas and said input gas with said purge gas is accomplished by simultaneously pumping and evacuating said purge gas.
19. The method of claim 12 wherein said reactive gas species is generated a distance between about 2 millimeters to about 4 millimeters above the surface of the substrate.
20. The method of claim 12 wherein said purge gas is selected from the group consisting of argon, nitrogen, helium, neon, and combinations thereof.

21. An atomic layer deposition method for forming monolayers on a surface of a substrate, comprising:

providing the substrate to a chamber having a gaseous atmosphere containing a transmission gas that is substantially nonattenuating to preselected wavelengths of electromagnetic radiation;

exposing the surface of the substrate to a precursor gas to form a surface reactant;

providing an input gas over the surface of the substrate simultaneously with said precursor gas;

preventing mixture of said precursor gas and said input gas with a purge gas;

directing a beam of electromagnetic radiation into said gaseous atmosphere, said beam converging said input gas in close proximity to the surface of the substrate, but spaced a finite distance therefrom, to dissociate said input gas into a high flux of generated reactive gas species; and

reacting said generated reactive gas species with said surface reactant to form at least a monolayer on at least a portion of the surface of the substrate.

22. The method of claim 21 wherein said precursor gas, said input gas, and said purge gas are each provided as a flow from a dispensing unit.

23. The method claim 22, wherein separating said precursor gas and said input gas is accomplished by simultaneously pumping and evacuating said purge gas.

24. The method of claim 22 further comprises causing relative motion between the surface of the substrate, said dispenser unit, and said beam to cause said dispenser unit and said beam to sweep over the surface of the substrate.

25. The method of claim 21 further comprises directing said beam of electromagnetic radiation from a laser source through a transparent window of said chamber into said gaseous atmosphere.

26. The method of claim 25 wherein said transparent window is a window selected from the group consisting of quartz, sapphire, and zinc selenide.

27. The method of claim 21 further comprises causing relative motion between the surface of the substrate and said beam to cause said beam to sweep over the surface of said substrate.

28. The method of claim 21 wherein said beam is in the range of wavelengths of about 193 nm to about 248 nm, and having energy in the range of about 100 to about 5000 mJ/cm<sup>2</sup>.

29. The method of claim 21, wherein said generated reactive gas species is selected from the group consisting of the noble gases, nitrogen, hydrogen, oxygen, and combinations thereof.

30. The method of claim 21 wherein said generated reactive gas species is selected from the group consisting of chlorine, fluorine, and molecules containing fluorine or chlorine.
31. The method of claim 21 wherein the input gas is selected from the group consisting of  $N_2O$ ,  $NO_2$ ,  $NH_3$ ,  $H_2$ ,  $H_2O$ ,  $N_2$ ,  $O_2$ ,  $O_3$ ,  $CCl_4$ ,  $BCl_3$ ,  $CDF_3$ ,  $CF_4$ ,  $SiH_4$ ,  $CFCl_3$ ,  $F_2CO$ ,  $(FCO)_2$ ,  $SF_5NF_2$ ,  $N_2F_4$ ,  $CF_3Br$ ,  $CF_3NO$ ,  $(CF_3)_2CO$ ,  $CF_2HCl$ ,  $CF_2HBr$ ,  $CF_2Cl_2$ ,  $CF_2Br_2$ ,  $CF_2CFCl$ ,  $CF_2CFH$ ,  $CF_2CF_2CH_2$ ,  $NH_3$ ,  $CHF_3$ , fluorohalides, halocarbons, and combinations thereof.
32. The method of claim 21 wherein the substrate is semiconductive.
33. The method of claim 21 further comprises controlling the energy characteristics of said beam to match absorption characteristics of said input gas to produce said high flux of said generated reactive gas species.
34. The method of claim 21 where said transmission gas is a gas or mixture of gases that is non-attenuating to predetermined wavelengths of said electromagnetic radiation.
35. The method of claim 21 wherein said transmission gas is selected from the group consisting of argon, nitrogen, helium, neon, and combinations thereof.
36. The method of claim 21 further comprises delivering a diagnostic beam of radiation to monitor formation of said monolayer on the surface of the substrate.

37. The method of claim 21 wherein said purge gas is selected from the group consisting of argon, nitrogen, helium, neon, and combinations thereof.

38. The method of claim 21 wherein said input gas is provided as a gas layer flown over the surface of the substrate and having a thickness that is at least large enough to accommodate said finite distance.

39. The method of claim 21 wherein said finite distance is selected from the about 2 millimeters to about 4 millimeters above the surface of the workpiece.

40. The method of claim 21 wherein said generated reactive gas species is selected from the group consisting of NO, OH, NH, N, F, CF<sub>3</sub>, CF<sub>2</sub>, CF, NF<sub>2</sub>, NF, Cl, O, BCl<sub>2</sub>, BCl, FCO, and combinations thereof.

41. An atomic layer deposition method for forming monolayers on a surface of a substrate, comprising:

loading the substrate into a reaction chamber;

pumping on said reaction chamber until a preselected pressure is achieved;

flowing simultaneously into said reaction chamber a precursor gas, a purge gas,

and an input gas;

forming a surface reactant by permitting said precursor gas to react with the surface of the substrate at selected locations;

evacuating said purge gas and any gases/residuals in vicinity of said purge gas to prevent mixing of the precursor and input gases;

delivering a beam of electromagnetic radiation into said input gas in close proximity to the surface of the substrate, but spaced a finite distance therefrom, to dissociate said input gas into a high flux of point of use generated reactive gas species; and

reacting said generated reactive gas with said surface reactant to form at least a monolayer at said selected locations.

42. The method of claim 41 further comprises flowing into said reaction chamber a transmission gas.

43. The method of claim 41 wherein said preselected pressure is from about 0.1 Torr to about 100 Torr.

44. The method of claim 41 wherein said monolayer is selected from the group consisting of elements and compounds.

45. The method of claim 41 further comprises checking formation of said monolayer on the surface of the substrate for completeness.

46. The method of claim 41 further comprises directing said beam through a window of said reaction chamber.

47. The method of claim 41 further comprises causing relative motion between the substrate and said beam.

48. The method of claim 41 wherein said flows of said input gas, precursor gas and purge gas are provided from a dispenser unit, wherein said dispenser unit further includes a pair of evacuation ports to evacuate at least said purge gas.

49. The method of claim 48 further comprises causing relative motion between the substrate, said beam, and said dispenser unit.

50. The method of claim 41 wherein said beam is in the range of wavelengths of about 193 nm to about 248 nm, and having energy in the range of about 100 to about 5000 mJ/cm<sup>2</sup>.

51. The method of claim 41 wherein said generated reactive gas species is selected from the group consisting of the noble gases, N, H, F, Cl, O, NO, OH, NH, CF<sub>3</sub>, CF<sub>2</sub>, CF, NF<sub>2</sub>, NF, BCl<sub>2</sub>, BCl, FCO, molecules containing fluorine or chlorine, and combinations thereof.

52. The method of claim 41 wherein the input gas is selected from the group consisting of N<sub>2</sub>O, NO<sub>2</sub>, NH<sub>3</sub>, H<sub>2</sub>, H<sub>2</sub>O, N<sub>2</sub>, O<sub>2</sub>, O<sub>3</sub>, CCl<sub>4</sub>, BCl<sub>3</sub>, CDF<sub>3</sub>, CF<sub>4</sub>, SiH<sub>4</sub>, CFCl<sub>3</sub>, F<sub>2</sub>CO, (FCO)<sub>2</sub>,

SF<sub>5</sub>NF<sub>2</sub>, N<sub>2</sub>F<sub>4</sub>, CF<sub>3</sub>Br, CF<sub>3</sub>NO, (CF<sub>3</sub>)<sub>2</sub>CO, CF<sub>2</sub>HCl, CF<sub>2</sub>HBr, CF<sub>2</sub>Cl<sub>2</sub>, CF<sub>2</sub>Br<sub>2</sub>, CF<sub>2</sub>CFCl, CF<sub>2</sub>CFH, CF<sub>2</sub>CF<sub>2</sub>CH<sub>2</sub>, NH<sub>3</sub>, CHF<sub>3</sub>, fluorohalides, halocarbons, and combinations thereof.

53. The method of claim 41 further comprises controlling the energy characteristics of said beam to match absorption characteristics of said input gas to produce said high flux of said generated reactive gas species.

54. The method of claim 42 where said transmission gas is a gas or mixture of gases that is non-attenuating to predetermined wavelengths of said electromagnetic radiation.

55. The method of claim 42 wherein said transmission gas is selected from the group consisting of argon, nitrogen, helium, neon, and combinations thereof.

56. The method of claim 41 wherein said purge gas is selected from the group consisting of argon, nitrogen, helium, neon, and combinations thereof.

57. The method of claim 41 wherein said input gas is provided as a gas layer flown over the surface of the substrate and having a thickness that is at least large enough to accommodate said finite distance.

58. The method of claim 41 wherein said finite distance is selected from the about 2 millimeters to about 4 millimeters above the surface of the workpiece.

59. An atomic layer deposition method for forming a monolayer on a surface of a substrate, comprising:

causing relative motion between the substrate, a dispenser unit, and a beam of electromagnetic radiation;

exposing the surface of the substrate to a precursor gas flowing from said dispenser unit to form a surface reactant thereon;

providing an input gas flowing from said dispensing unit above the surface of the substrate simultaneously with said precursor gas;

providing a purge gas flowing from said dispensing unit to prevent mixing of said precursor gas and said input gas;

generating a high flux of reactive gas species from said input gas with said beam of electromagnetic radiation; and

reacting said reactive gas species with said surface reactant to form a monolayer on at least a portion of the surface of the substrate.

60. The method of claim 59 wherein said generated reactive gas species is selected from the group consisting of the noble gases, N, H, F, Cl, O, NO, OH, NH, CF<sub>3</sub>, CF<sub>2</sub>, CF, NF<sub>2</sub>, NF, BCl<sub>2</sub>, BCl, FCO, molecules containing fluorine or chlorine, and combinations thereof.

61. The method of claim 59 wherein the input gas is selected from the group consisting of N<sub>2</sub>O, NO<sub>2</sub>, NH<sub>3</sub>, H<sub>2</sub>, H<sub>2</sub>O, N<sub>2</sub>, O<sub>2</sub>, O<sub>3</sub>, CCl<sub>4</sub>, BCl<sub>3</sub>, CDF<sub>3</sub>, CF<sub>4</sub>, SiH<sub>4</sub>, CFCl<sub>3</sub>, F<sub>2</sub>CO, (FCO)<sub>2</sub>,

SF<sub>5</sub>NF<sub>2</sub>, N<sub>2</sub>F<sub>4</sub>, CF<sub>3</sub>Br, CF<sub>3</sub>NO, (CF<sub>3</sub>)<sub>2</sub>CO, CF<sub>2</sub>HCl, CF<sub>2</sub>HBr, CF<sub>2</sub>Cl<sub>2</sub>, CF<sub>2</sub>Br<sub>2</sub>, CF<sub>2</sub>CFCl, CF<sub>2</sub>CFH, CF<sub>2</sub>CF<sub>2</sub>CH<sub>2</sub>, NH<sub>3</sub>, CHF<sub>3</sub>, fluorohalides, halocarbons, and combinations thereof.

62. The method of claim 59 wherein the substrate is semiconductive.
63. The method of claim 59 wherein said monolayer is selected from the group consisting of elements and compounds.
64. The method of claim 59 wherein said electromagnetic radiation is in the range of wavelengths of about 193 nm to about 248 nm, and having energy in the range of about 100 to about 5000 mJ/cm<sup>2</sup>.
65. The method of claim 59 wherein preventing the mixture of said precursor gas and said input gas with said purge gas is accomplished by simultaneously flowing and evacuating said purge gas.
66. The method of claim 59 wherein said beam is delivered into said input gas in close proximity to the surface of the substrate, but spaced a finite distance therefrom.
67. The method of claim 59 wherein said reactive gas species is generated a distance between about 2 millimeters to about 4 millimeters above the surface of the substrate.

68. The method of claim 59 further comprises directing said beam of electromagnetic radiation from a laser source through a transparent window of a reaction chamber into said input gas.

69. The method of claim 68 wherein said transparent window is a window selected from the group consisting of quartz, sapphire, and zinc selenide.

70. The method of claim 59 wherein said relative motion causes said dispenser unit and said beam to sweep over the surface of the substrate.

71. The method of claim 68 further comprises directing said beam of electromagnetic radiation through a gaseous atmosphere provided in said reaction chamber before being delivered into said input gas.

72. The method of claim 71 wherein said transmission gas is a gas or mixture of gases that is non-attenuating to predetermined wavelengths of said electromagnetic radiation.

73. The method of claim 71 wherein said transmission gas is selected from the group consisting of argon, nitrogen, helium, neon, and combinations thereof.

74. The method of claim 59 further comprises controlling the energy characteristics of said beam to match absorption characteristics of said input gas to produce said high flux of said generated reactive gas species.

75. The method of claim 59 further comprises delivering a diagnostic beam of radiation to monitor formation of said monolayer on the surface of the substrate.

76. The method of claim 59 wherein said purge is selected from the group consisting of argon, nitrogen, helium, neon, and combinations thereof.

77. The method of claim 66 wherein said input gas is provided as a gas layer flow over the surface of the substrate having a thickness that is at least large enough to accommodate said finite distance.

78. The method of claim 66 wherein said finite distance is selected from the about 2 millimeters to about 4 millimeters above the surface of the workpiece.